



Self-reported chronic rhinosinusitis diagnoses and symptoms in World Trade Center-exposed and non-World Trade Center-exposed United States firefighters

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ABSTRACT

Background: Greater World Trade Center (WTC) exposure levels have been associated with chronic rhinosinusitis (CRS) diagnoses and symptoms. We aimed to determine whether self-reported CRS is elevated in WTC-exposed Fire Department of the City of New York (FDNY) firefighters when compared with non-WTC-exposed/non-FDNY firefighters and with the general population.

Methods: The study included male WTC-exposed ($N = 7840$) and non-WTC-exposed ($N = 2771$) firefighters who were employed on 9/11/2001 and later completed a health survey. Self-reported CRS diagnoses and symptoms were evaluated. Multivariable logistic regression analyses estimated the odds of self-reported ever CRS diagnosis and current symptoms in WTC-exposed vs. non-WTC-exposed firefighters. Additional analyses compared self-reported current CRS diagnoses in firefighters vs. American males. Models were adjusted for demographics, smoking, and BMI.

Results: Fifty-one percent of WTC-exposed firefighters reported ever having a CRS diagnosis vs. 20 % of non-WTC-exposed firefighters (adjusted-OR = 3.84, 95 % CI = 3.44–4.28). WTC-exposure was also associated with specific rhinosinusitis symptoms, including nasal/sinus congestion (adjusted-OR = 1.17, 95 % CI = 1.06–1.29), nose irritation (adjusted-OR = 1.48, 95 % CI = 1.24–1.76), and sinus pain/pressure (adjusted-OR = 1.42, 95 % CI = 1.26–1.60). Both WTC-exposed (adjusted-OR = 3.84, 95 % CI = 3.46–4.27) and non-WTC-exposed firefighters (adjusted-OR = 1.97, 95 % CI = 1.71–2.27) were more likely to report a current CRS diagnosis than similar adult males.

Conclusions: WTC-exposure was associated with self-reported CRS diagnoses and symptoms in firefighters. Higher CRS diagnosis prevalence in the WTC-exposed cohort could be a result of exposure to irritants present at the WTC site, and may also be explained, in part, by the enhanced surveillance and healthcare WTC-exposed firefighters receive via the WTC Health Program. Elevated levels of CRS in firefighters overall could be due to routine, non-WTC-related firefighting exposures.

1. Introduction

Chronic rhinosinusitis (CRS) symptoms including nasal congestion/obstruction, nasal discharge, sinus pain/pressure, and dysosmia are common among United States adults, with 10–15 % self-reporting current CRS symptoms or a CRS diagnosis in cross-sectional studies (Bhattacharyya and Gilani, 2018; Palmer et al., 2019; Centers for Disease Control and Prevention, 2022). Estimates of the actual prevalence

of CRS in the United States vary along with the CRS definition used. Individuals experiencing two or more rhinosinusitis symptoms over at least 12 weeks with objective evidence of inflammation on an endoscopy or sinus computed tomography scan meet a commonly accepted clinical definition of CRS (Bachert et al., 2014; Sundaresan et al., 2015). Studies using this or a similar case definition have estimated the population prevalence to be between two to 5 % (Bhattacharyya and Gilani, 2018; Sedaghat et al., 2022). The prevalence tends to be higher in certain

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occupational cohorts, however, as there is evidence of an association between occupational exposure to irritants and CRS (Thilsing et al., 2012; Beule, 2015; Gao et al., 2016; Clarhed et al., 2018; Clarhed et al., 2020).

Responders performing rescue/recovery work at the World Trade Center (WTC) disaster site on and after 9/11/2001 (9/11) were subject to a massive airborne particulate matter exposure (Liroy et al., 2002). The WTC dust was highly alkaline and contained pulverized construction materials including cement, glass fibers, asbestos, and lead and other metals, as well as products of combustion from the fires at the site (Liroy et al., 2002; Landrigan et al., 2004). Internal analyses involving WTC-exposed first responders have shown that higher intensity WTC dust/smoke exposure is associated with various respiratory diagnoses and symptoms (Webber et al., 2009; Weakley et al., 2016; Putman et al., 2018; Zeig-Owens et al., 2018). Among Fire Department of the City of New York (FDNY) firefighters, earlier arrival time and longer work duration at the WTC site were independently associated with a higher prevalence of CRS symptoms in the initial years post-9/11 (Webber et al., 2009). Early WTC site arrival was also linked to incident CRS diagnosis in this cohort (Weakley et al., 2016). Certain job tasks at the site that involved greater irritant exposures, such as the combination of digging/rescue work, were associated with CRS diagnoses in FDNY firefighters and emergency medical services providers (Putman et al., 2018). When comparing WTC-exposed firefighters with the United States general population, we found that the firefighters had persistently elevated rates of self-reported CRS diagnoses by a healthcare professional and CRS-related symptoms during 2005–2009 (Weakley et al., 2011). Until now, no study investigating CRS in WTC responders has used an appropriate, non-WTC-exposed comparison population with similar occupational exposures, such as those associated with routine firefighting.

In the current study, we aimed to determine whether self-reported CRS is elevated in WTC-exposed FDNY firefighters when compared with levels in a similar occupational cohort of non-WTC-exposed firefighters from the Chicago, Philadelphia, and San Francisco fire departments (Zeig-Owens et al., 2021). We assessed both self-reported CRS diagnoses by a healthcare professional and CRS symptoms as outcomes. We also investigated the relationship between firefighting exposures and CRS by comparing self-report of CRS diagnoses in both groups of career firefighters (WTC-exposed and non-WTC-exposed) vs. in the United States general population.

2. Materials and methods

2.1. Study population

This study included a subset of the male WTC-exposed and non-WTC-exposed firefighters enrolled in the Career Firefighter Health Study cohort (Zeig-Owens et al., 2021). Females were excluded ($N = 22$ WTC-exposed and $N = 197$ non-WTC exposed) due to low numbers in the WTC-exposed group. The WTC-exposed population consisted of FDNY firefighters who were actively employed on 9/11, first arrived at the WTC site between 9/11/2001–9/24/2001, and completed at least one post-9/11 self-administered health questionnaire at a FDNY WTC Health Program routine medical monitoring exam between 2/15/2019–5/1/2021, the same time period as when the non-WTC-exposed firefighter cohort's health questionnaire was administered. The final WTC-exposed firefighter population included 7840 participants.

The non-WTC-exposed firefighters included those who were actively employed by either the Chicago, Philadelphia or San Francisco Fire Department (CFD, PFD, and SFFD, respectively) on 9/11 and later completed a self-administered health questionnaire similar to the FDNY medical monitoring questionnaire, the Career Firefighter Health Study (CFHS) health survey, between 2/15/2019–5/1/2021 (Zeig-Owens et al., 2021). Among the population of 8813 male CFD, PFD and SFFD firefighters who had active employment at their respective fire

department on 9/11, 2771 completed the CFHS health survey and confirmed that they were not involved in the WTC rescue/recovery effort. The final study cohort included 10,611 firefighters. All participants provided written informed consent. The Albert Einstein College of Medicine/Montefiore Medical Center Institutional Review Board approved this study (IRB#: 2016–6396).

2.2. Firefighters' demographic, lifestyle, and WTC exposure data

Participants' dates of birth and employment, sex, and race/ethnicity were retrieved from the respective fire department employee databases. For WTC-exposed firefighters, height and weight measurements were taken during FDNY medical monitoring exams. WTC-exposed FDNY firefighters receive routine medical monitoring even after retirement. Self-administered health questionnaires are completed at the time of FDNY monitoring exam, about every 12 to 18 months. Smoking status (current, former or never smoker) was taken from their latest health questionnaire before 5/1/2021. WTC exposure information was obtained from the first post-9/11 questionnaire, in which participants reported their initial arrival time at the WTC site. Level of WTC exposure was classified as follows: we categorized FDNY members who arrived at the site on the morning of 9/11 as having the highest exposure, followed in order by members arriving during the afternoon of 9/11, on 9/12/2001, and lastly, between 9/13–9/24/2001.

Non-WTC-exposed firefighters completed the CFHS health survey once, between 2/15/2019 and 5/1/2021, and on it reported their height, weight, smoking status and confirmation of non-WTC exposure status.

2.3. Firefighters' CRS and symptom data

All participants reported whether or not they had ever received a CRS diagnosis from a healthcare professional (self-reported ever CRS diagnosis) on the health surveys. The baseline FDNY health monitoring survey asked if the member had ever received a CRS diagnosis, and subsequent surveys inquired about diagnoses within the previous 12 months. As such, to determine whether FDNY participants ever self-reported a CRS diagnosis, we combined data from post-9/11 FDNY health surveys completed before 5/1/2021. If a FDNY participant ever reported receiving a CRS diagnosis from a healthcare professional within the past 12 months, they were flagged as having a self-reported ever CRS diagnosis. Those who responded yes to the past 12 months CRS diagnosis question on their first survey taken between 2/15/2019 and 5/1/2021, the CFHS survey administration period, had a self-reported *current* CRS diagnosis.

Both WTC- and non-WTC-exposed firefighters also reported on the surveys whether they had experienced CRS symptoms within the past 12 months. Specifically, they were asked "In the past 12 months, apart from when you had a cold or flu, did you have any of the following symptoms?" The list of upper respiratory symptoms included frequent headaches, sinus or facial pain/pressure, nasal or sinus congestion, runny nose/postnasal drip, nose irritation/soreness/burning, and frequent nosebleeds. Survey respondents who said yes to one or more of these during the 2/15/2019–5/1/2021 period were flagged as having current CRS symptoms. We used the current symptoms data to create a self-reported current CRS diagnosis flag for the non-WTC-exposed firefighters, since the CFHS health survey only assessed whether they *ever* received a CRS diagnosis. CFHS survey respondents who reported ever having a CRS diagnosis and selected at least one current CRS symptom were considered to have a self-reported *current* CRS diagnosis.

2.4. United States population data

We used data from the 2018 National Health Interview Survey (NHIS) to assess the prevalence in the United States general population of a self-reported CRS diagnosis by a healthcare professional (National

Center for Health Statistics, 2023). On the 2018 NHIS, the most recent version to include a CRS question, participants were asked “During the past 12 months, have you been told by a doctor or other health professional that you had... sinusitis?”; those who answered yes were flagged as having a self-reported current CRS diagnosis. NHIS participants also reported their age in 2018, sex, race/ethnicity, smoking status, height, weight, and the region of the country in which they resided. We restricted the NHIS comparison population for this study to adult males who did not reside in the South ($N = 7384$) in order to make the sample more comparable to the firefighter cohorts.

2.5. Statistical analyses

Demographic and lifestyle characteristics of the firefighter cohorts were assessed as proportions (%) or means ($\pm$ standard deviation). Crude self-reported CRS diagnosis and symptom prevalences were calculated for both WTC-exposed and non-WTC-exposed firefighters. We used multivariable logistic regression to estimate the OR and 95 % CI of self-reported ever CRS diagnosis in WTC-exposed vs. non-WTC-exposed firefighters, controlling for age on 9/11, race/ethnicity, ever smoking, and body mass index (BMI). We then repeated the analysis using an ordinal variable to classify WTC exposure level in the multivariable logistic regression model; the exposure level variable ranged from zero to four, with zero representing the non-WTC-exposed group and four representing the highest exposure group.

In a sensitivity analysis, we accounted for the fact that WTC-exposed firefighters had more opportunities to self-report a CRS diagnosis than did non-WTC-exposed firefighters. WTC-exposed members were considered to have self-reported a CRS diagnosis if they answered “yes” to the CRS diagnosis question ≥ 50 % of the time after their initial survey reporting it. We then repeated the primary analysis using this restricted outcome variable.

Additional analyses compared current CRS symptoms in the WTC and non-WTC firefighters. Multivariable logistic regression analyses estimated the associations (ORs and 95 % CIs) of binary WTC exposure with self-report of frequent headaches, sinus pain/pressure, nasal/sinus congestion, runny nose/postnasal drip, nose irritation/soreness/burning, and frequent nosebleeds, controlling for age at survey completion, race/ethnicity, ever smoking, and BMI.

Lastly, we fit two multivariable logistic regression models estimating associations between firefighting exposures and self-reported current CRS diagnosis: first with a binary exposure variable comparing firefighters overall (combined WTC- and non-WTC-exposed) to the general population, and then assessing WTC-exposed and non-WTC-exposed firefighting as separate categories and comparing the outcome in each firefighter cohort vs. in the general population. Models included the covariates listed above.

All reported p -values are two-sided and considered statistically significant when $p < 0.05$. Data analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, NC).

3. Results

3.1. Study population characteristics

Table 1 contains demographics and other characteristics of the WTC-exposed and non-WTC-exposed firefighter populations. WTC-exposed firefighters were younger, on average, than the non-WTC-exposed firefighters. The WTC-exposed cohort also had a higher proportion of non-Hispanic whites and a lower proportion of ever smokers than the non-WTC-exposed group. Fig. 1 shows the crude percentages of self-reported ever CRS diagnosis and current CRS symptoms in each firefighter cohort. About half (51 %) of the WTC firefighters reported ever being diagnosed with CRS by a healthcare professional, compared with 20 % of the non-WTC-exposed. The most commonly reported current CRS symptoms in the WTC-exposed and non-WTC-exposed groups were

Table 1
Characteristics of World Trade Center-exposed and non-World Trade Center-exposed male career firefighters at baseline (9/11/2001) and at time of health survey completion (2/15/2019–5/1/2021).

	WTC-exposed	Non-WTC-exposed
N	7840	2771
Age on 9/11, mean ($\pm$ SD)	40.3 ($\pm$ 7.3)	44.1 ($\pm$ 8.8)
Age at survey completion, mean ($\pm$ SD)	58.3 ($\pm$ 7.3)	62.2 ($\pm$ 8.8)
Race, N (%)		
White	7411 (94.5)	2094 (75.5)
Black	166 (2.1)	307 (11.1)
Hispanic	241 (3.1)	224 (8.1)
Other	22 (0.3)	146 (5.3)
BMI, mean ($\pm$ SD)	29.6 ($\pm$ 4.4)	29.0 ($\pm$ 4.4)
Ever smokers, N (%)	2547 (32.5)	1187 (42.8)
Medical visit within two years, N (%)	7840 (100.0)	2669 (96.3)
WTC exposure, N (%)		
Morning of 9/11	1259 (16.0)	
Afternoon of 9/11	4271 (54.5)	
9/12/2001	1368 (17.5)	
9/13–9/24/2001	942 (12.0)	

Abbreviations: World Trade Center (WTC), standard deviation (SD), body mass index (BMI).

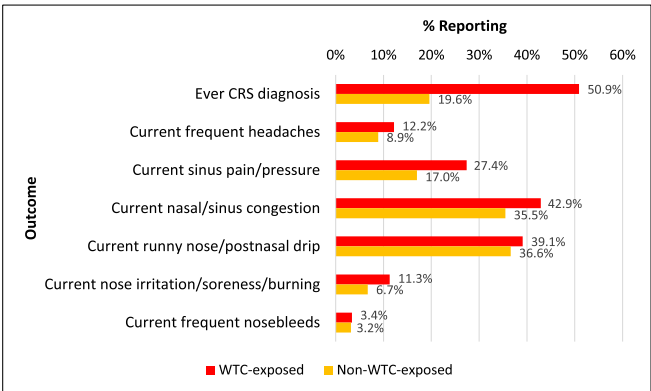


Fig. 1. Self-report of chronic rhinosinusitis diagnosis and current chronic rhinosinusitis-related symptoms in male World Trade Center-exposed and non-World Trade Center-exposed firefighters. The percentage of each firefighter cohort that reported ever receiving a chronic rhinosinusitis diagnosis, and percentages reporting current chronic rhinosinusitis-related symptoms. Abbreviations: Chronic rhinosinusitis (CRS), World Trade Center (WTC).

nasal/sinus congestion (43 %) and runny nose/postnasal drip (37 %), respectively. The least common symptom in both groups was frequent nosebleeds (~ 3 % in both).

The WTC firefighter cohort also had a higher percentage of individuals self-reporting a current CRS diagnosis (28 %) than both the non-WTC firefighter cohort (16 %) and the general population (8 %).

3.2. Odds of self-reported CRS in WTC-exposed vs. non-WTC-exposed firefighters

Multivariable-adjusted associations of WTC exposure with self-reported ever CRS diagnosis and current CRS symptoms in firefighters are displayed in Fig. 2. After controlling for age on 9/11, race/ethnicity, ever smoking and BMI in a multivariable logistic regression model, the odds of a self-reported ever CRS diagnosis were almost four times higher in the WTC-exposed firefighters vs. the non-WTC-exposed (OR = 3.84, 95 % CI = 3.44–4.28). We also detected a dose-response relationship between WTC exposure level and CRS: with each increase in WTC exposure level there was a 42 % greater odds of a self-reported ever CRS diagnosis (OR = 1.42, 95 % CI = 1.38–1.47) (data not shown).

In a sensitivity analysis in which we used the stricter definition for

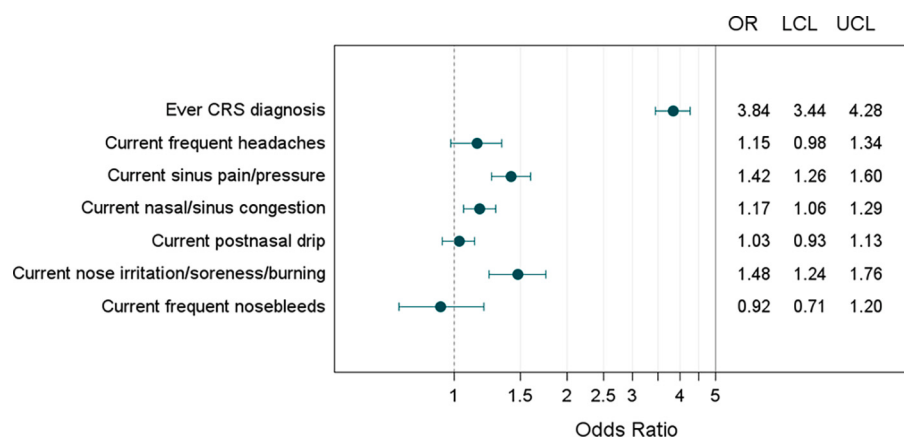


Fig. 2. ORs and 95 % CIs of self-reported ever chronic rhinosinusitis diagnosis and current rhinosinusitis symptoms in World Trade Center-exposed firefighters vs. non-World Trade Center-exposed firefighters, adjusting for age, race/ethnicity, ever smoking, and body mass index. Abbreviations: Chronic rhinosinusitis (CRS), lower confidence limit (LCL), upper confidence limit (UCL).

self-reported ever CRS diagnosis in the WTC-exposed cohort to account for their additional opportunities to report CRS, we again observed a multivariable-adjusted association between WTC exposure and self-reported CRS; however, it was attenuated. WTC-exposed firefighters were 86 % more likely to have self-reported CRS than their non-WTC-exposed counterparts (OR = 1.86, 95 % CI = 1.66–2.08) (data not shown).

Analyses estimating current CRS symptoms showed that WTC-exposed firefighters had modestly elevated odds of self-reported sinus pain/pressure, nasal/sinus congestion, and nose irritation/soreness/burning within the previous 12 months, controlling for age at time of survey, race/ethnicity, ever smoking and BMI (Fig. 2). We did not observe a significant association between WTC exposure and current frequent headaches, frequent nosebleeds, or postnasal drip.

3.3. Odds of self-reported CRS diagnosis in firefighters vs. the general population

Firefighters overall (combined WTC- and non-WTC-exposed) were significantly more likely to have self-reported current CRS diagnoses than the general population after controlling for potential confounders (OR = 3.33, 95 % CI = 3.00–3.69). When WTC firefighters and non-WTC firefighters were assessed as separate categories in the model, both groups had significantly elevated odds of self-reported current CRS diagnosis compared with the general population, controlling for age, race/ethnicity, ever smoking and BMI. WTC-exposed male firefighters were almost four times more likely to report having a current CRS diagnosis than United States males (OR = 3.84, 95 % CI = 3.46–4.27), and non-WTC-exposed firefighters were approximately twice as likely to report having one (adjusted-OR = 1.97, 95 % CI = 1.71–2.27).

4. Discussion

This is the first investigation of CRS in WTC rescue/recovery workers that used a similar non-WTC-exposed occupational cohort as a reference population. Occupational irritant exposures, such as routine firefighting exposures, have been associated with respiratory conditions and symptoms, including those related to CRS (Gaughan et al., 2008; Koh et al., 2009; Greven et al., 2011; Crawford and Graveling, 2012; Thilsing et al., 2012; Gao et al., 2016; Gianniou et al., 2018; Alkholaiwi et al., 2022). In the present analyses, we estimated the effect of WTC rescue/recovery work on CRS while controlling for firefighting occupation. We compared CRS outcomes in WTC-exposed firefighters to those in non-WTC-exposed firefighters as well as in the general population. WTC exposure was associated with a nearly four-fold increase in the odds of subsequent self-reported CRS diagnosis and a modest but significant increase in the odds

of self-reported CRS symptoms within career firefighters.

Our results are consistent with those from earlier internal analyses in the FDNY WTC-exposed rescue/recovery worker cohort, which showed that earlier WTC site arrival time was associated with increased risk of CRS diagnosis or CRS symptoms, compared with WTC site arrival after 9/13/2001 (Webber et al., 2009; Weakley et al., 2016; Putman et al., 2018). We also showed that cohort members diagnosed with CRS had lower physical health-related quality of life scores, on average, than members without any WTC exposure-related illnesses and than United States general population norms (Yip et al., 2016). WTC-exposed workers have also had consistently higher rates of CRS diagnoses when compared with the United States general population. Another previous study using the FDNY WTC-exposed cohort and NHIS data demonstrated an elevated prevalence of self-reported CRS diagnoses in WTC-exposed firefighters compared with demographically similar American adults during the years 2005–2009 (Weakley et al., 2011). In the current investigation, we found that WTC-exposed firefighters continued to be significantly more likely to report a current CRS diagnosis than the United States general population, even 18+ years after the WTC rescue/recovery effort.

A key finding of this study was that levels of self-reported CRS diagnosis were elevated among WTC-exposed firefighters even when compared with similar, non-WTC-exposed firefighters. The higher prevalence of self-reported CRS diagnoses in the WTC firefighter cohort could be due to WTC-related exposures, i.e., repeated exposure to irritants in the WTC dust/smoke resulting in chronic inflammation of the respiratory tract leading to diagnoses and symptoms years later. An important indicator that WTC exposure impacted CRS diagnosis was the dose-response relationship observed between WTC exposure intensity and self-reported ever CRS diagnoses. Additionally, three common CRS symptoms (sinus pain/pressure, nasal/sinus congestion, and nose irritation/soreness/burning) were elevated in the WTC-exposed firefighters compared with the non-WTC-exposed. The associations between WTC exposure and current CRS symptoms suggest a more modest effect of WTC rescue/recovery work on CRS than the results of our primary analysis, however, as these ORs were attenuated compared to the association between WTC exposure and self-reported CRS diagnosis.

We also observed that firefighters overall had a greater prevalence of self-reported CRS diagnoses by a healthcare professional than the general population. Non-WTC-exposed firefighters were twice as likely to report having a current CRS diagnosis as United States adult males. This difference may be partly explained by greater healthcare access/utilization in the firefighters, as career firefighters have health insurance via their employment, although our findings are consistent with results from previous studies of CRS in non-firefighter occupational cohorts. Prevalence of CRS was higher in occupations where workers are routinely

exposed to dust, gases, smoke, fumes, or physically strenuous tasks (Koh et al., 2009; Thilsing et al., 2012; Gao et al., 2016; Clarhed et al., 2018; Alkholaiwi et al., 2022). Given that CRS is associated with loss of productivity, reduced health-related quality of life, and depression (Rudmik and Smith, 2011; Lange et al., 2013; Beule, 2015; DeConde and Soler, 2016; Schlosser et al., 2016; Rudmik, 2017), it is imperative that workers in high-risk occupations have access to effective personal protective equipment and medical care.

The associations between firefighting exposures and CRS that have been shown in multiple studies underscore the importance of having an appropriate occupational comparison population when assessing possible health effects of WTC exposure in firefighters. The primary strength of our study was that we were able to compare WTC-exposed FDNY firefighters to non-WTC-exposed urban firefighters who were also actively employed on 9/11. In addition to having similar work exposures, both groups of firefighters had to have met strict hiring criteria including the health requirements imposed by urban fire departments (National Fire Protection Association, 1992), making them similarly healthy at baseline. Previous investigations that were conducted within the CFHS cohort and therefore also able to control for firefighting occupation showed greater odds of self-reported obstructive airways disease and cardiovascular disease in WTC-exposed firefighters, as compared to non-WTC exposed firefighters (Mueller et al., 2023; Mueller et al., 2024).

The main limitation of this study is the reliance on self-reported data, particularly for CRS diagnosis by a healthcare professional. This could have led to misclassification of diagnosis status in both the firefighter groups and in the general population. We also relied on self-report for CRS symptoms, smoking status and WTC arrival time. A second limitation was the possibility of surveillance/detection bias, which would lead to ORs biased away from the null in analyses predicting CRS diagnosis. Career firefighters overall likely have greater healthcare utilization than the US general population due to their employment benefits, and WTC-exposed FDNY cohort members additionally receive no-cost health monitoring and treatment for conditions deemed to be exposure-related via the WTC Health Program (Centers for Disease Control and Prevention, 2024). However, we believe any impact on our primary analysis was minimal because the non-WTC-exposed career firefighters in this study have health insurance, with 96 % reporting a healthcare visit within the prior two years. Additionally, the results from the sensitivity analysis that used a more conservative definition for CRS diagnosis in the WTC-exposed and our analyses predicting recent CRS symptoms in the firefighters indicate a significant effect of WTC exposure on CRS.

5. Conclusion

CRS prevalence in firefighters involved in the WTC rescue/recovery effort was elevated beyond levels expected from routine urban firefighting exposures. The greater prevalence of CRS diagnoses in firefighters, both WTC- and non-WTC-exposed, compared with demographically similar United States adults, highlights the importance of ensuring comprehensive healthcare coverage in high-risk occupational cohorts.

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CRedit authorship contribution statement

Ankura Singh: Writing – original draft, Investigation, Formal analysis, Data curation. **Rachel Zeig-Owens:** Writing – review & editing, Supervision, Project administration, Methodology, Conceptualization. **Mayris P. Webber:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization. **Alexandra K. Mueller:** Writing – review & editing, Formal analysis, Data curation. **David J. Prezant:** Writing – review & editing, Visualization, Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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